ON DISTANCE ANTIMAGIC LABELING OF GRAPHS AND THEIR PRODUCTS

Synopsis of the PhD Thesis

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ABSTRACT

In graph theory, antimagic labeling refers to assigning distinct positive integers to each vertex and vertex's edges in order to have a unique sum of labels incident to each vertex. This characteristic facilitates the analysis and differentiation of graphs.The study of antimagic labeling is primarily driven by its applications in network design, cryptography, and resource allocation, where distinct identifiers or configurations play a crucial role in ensuring security and optimising performance. One of the main advantages of antimagic labeling is that it uses edge labels to encode information, which helps with graph representation, data encoding, and combinatorial problems. The study on antimagic labeling naturally paves way for distance antimagic labeling which takes into account the spatial interactions between vertices. This development illustrates the depth and usefulness of antimagic notions in both theory and practice.

The initial component of the thesis examines the presence and absence of distance antimagic labeling in particular categories of graphs. This study employs a computer-assisted method to determine the distance antimagic labeling for the Kneser graph and the bipartite Kneser graph. The study further examines distance antimagic labeling for a class of disconnected graphs and presents evidence for distance antimagic labeling in cycle-related graphs. In the next section, distance antimagic labeling on various basic graph products is discussed. The graph products taken into consideration are the Cartesian product, lexicographic product, tensor product, and strong product. Graph products are utilized in many other fields and are crucial to graph theory. Graph products are used in network design to construct complex topologies with specific characteristics and connections. There are multiple applications for labeling graph products in engineering

disciplines.

In the next part of the thesis, we discuss the existence and non-existence of inclusive distance antimagic labeling of different classes of graphs and graph products. This work investigates the inclusive distance antimagic labeling of closed helm graphs and helm raphs. The concept of inclusive distance antimagic labeling for a family of disconnected graphs of helm graphs is further explored in this thesis. This study also presents findings on inclusive distance antimagic labelling of products of graphs, such as the join of graphs, Cartesian product, corona product, and rooted product. Inclusive distance antimagic labelling developed in this study can serve as a paradigm in areas with analogous connection methodologies, particularly in communication networks and coding theory.

This study also highlights distance antimagic and inclusive distance antimagic labeling of certain special classes of graphs, such as splitting graphs, shadow graphs, and Mycielski graphs, for basic classes of graphs. The specified special classes of graphs are important concepts in graph theory, wherein the original graph is altered by the addition of vertices or edges to investigate new properties or relationships. The labeling of these graphs facilitates modeling in real-world issues such as communication networks, transportation networks, and optimization problems in graph algorithms.

In the last section of the thesis, distance antimagic and inclusive distance antimagic labeling finds specific application in cryptology. This labeling presents an innovative and mathematically correct framework for encryption, delivering improved security, distinctiveness, and flexibility.

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CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Graph theory is the basis of discrete mathematics. It is widely used in computer science, biology, social networks and communication systems. Graph labeling is an important method for inspecting and encoding graph structure. Distance antimagic labeling is a specialised notion within graph theory, notable for its theoretical importance and diverse practical applications.

Distance antimagic labeling is a labeling scheme that assigns integers to the vertices of a graph in such a way that the weighted sums of vertex labels in any given neighborhood are distinct. A strong framework for assessing symmetry, graph embedding, and optimal resource allocation is offered by this special feature. In network theory, for instance, distance antimagic labeling helps to improve resource allocation and routing protocols by giving vertices specific weights. This labeling is crucial for examining problems that call for the separation and classification of graph components according to their structural properties. Distance antimagic labeling provides systems a unique code for error detection in coding theory. This labeling technique helps to identify structural characteristics of graphs such as isomorphism and symmetry that aids in understanding of graph classification. This leads to better understanding of behavior of graph families based on label-based invariants.

It is important to have concepts such as distance antimagic labeling since these relate

theory to practice. The implications of this phenomenon go further into theoretical studies on graph invariants which are fundamental tools in graph structure study. It might reveal new combinatorial properties of types of graphs, such as trees, cycles, and bipartite graphs, to study the behavior of distance antimagic labeling in different classes of graphs. It would also be related to designing data encoding systems and secure communication networks because different weights would guarantee the absence of conflicts in the data transfer and unique paths in separate situations. This label may also find application in bioinformatics, where biological systems such as networks of protein-protein interactions or metabolic pathways are often modeled with graphs. Different weights can isolate crucial nodes or paths in these networks.

In several different sectors, distance antimagic labeling enhances functionality and efficiency in unique ways. It provides nodes with unique identity that enhances routing algorithms, and prevents data collisions to ensure non-overlapping communication channels in communication networks. In coding and cryptography, this labeling technique aids in the design of secure coding schemes for reliable data encoding and transmission through the unique labeling of graph components. Assignment of unique weights to vertices of graphs enables a more thorough comprehension of interactions in social network analysis by finding key nodes. Similarly, bioinformatics facilitates biological network analysis and the identification of discrete entities and their interactions by uniquely labeling functional modules or pathways. In sensor networks and robotics distance antimagic labeling helps to optimise pathfinding algorithms which is crucial for figuring out the best route. Also, this labeling aids in sensor placement strategies by accurate modelling the dealt spaces. In the realms of game theory and puzzle design, this concept also plays a role in opening up avenues for creating fresh strategies and solutions. This means games and puzzles having unique configurations will be easier to design using this notion. Theoretical studies and applied innovation in graph theory are expected to be significantly improved by distance antimagic labeling as the field advances.

1.2 DEFINITIONS

This section contains basic definitions of antimagic labeling, distance magic labeling, distance antimagic labeling and inclusive distance antimagic labeling which will be required throughout the thesis.

Definition 1.2.1. A graph G with m edges and n vertices is said to have an antimagic labeling if it has a one-to-one correspondence $h : E(G) \to \{1, 2, \ldots, m\}$ such that for distinct vertices $a, b \in V(G)$, $\mu(a) \neq \mu(b)$ where $\mu(a)$ is defined as the sum of the labels of the edges that are incident to vertex a in G. An antimagic graph is ont that has at least one antimagic labeling.

Definition 1.2.2. The term distance magic labeling refers to a bijection $h : V(G) \to \{1, 2, ..., n\}$ if there exists a positive integer m such that $\sum_{a \in N(u)} h(a) = m$, where $N(u)$ is the open neighborhood of u. The constant m of the labeling h is referred to as the magic constant of the labeling. Any graph which allows a distance magic labeling is called a distance magic graph.

Definition 1.2.3. If for every pair of unique vertices $a, b \in V(G)$, $\mu(a) \neq \mu(b)$ then bijection $h\colon V(G) \to \{1, 2, \ldots, n\}$ is called distance antimagic labeling. Here $\mu(b) = \sum_{a \in N(b)} f(a)$ is weight of vertex b and $N(b)$ is open neighbourhood of $b \in V(G)$. Then G is referred to as distance antimagic graph if it permits such a labeling.

Definition 1.2.4. Let h be a bijection such that $h\colon V \to \{1, 2, \ldots, n\}$. Let weight of any vertex $b \in V(G)$ be defined as $\mu(b) = h(b) + \sum_{a \in N(b)} h(a)$. h is referred to as inclusive distance antimagic labeling if for every two unique vertices $a, b \in V(G)$, $\mu(a) \neq \mu(b)$. G is referred to be an inclusive distance antimagic graph if such a labeling is present.

1.3 OBJECTIVES OF THE WORK

1. Development and analysis of distance antimagic labeling of product graphs: To establish conditions for existence and non-existence of distance antimagic labeling of different graph products.

2. Computation of distance antimagic labeling through computer-aided techniques: To compute distance antimagic labeling for specific classes of graphs using Python programming which was a tedious task to calculate manually.

3. Extension and analysis of distance antimagic labeling: To extend the results of distance antimagic labeling to inclusive distance antimagic labeling and explore labeling of some special classes of graphs and graph products.

4. Application of distance antimagic labeling in crytography: To demonstrate the practical application of distance antimagic and inclusive distance antimagic for encryption of data in cryptography. These objectives collectively seek to deliver a concentrated and thorough investigation of distance antimagic labeling, encompassing both theoretical dimensions and practical ramifications in cryptography and network modelling.

CHAPTER 2

LITERATURE REVIEW

2.1 ANTIMAGIC LABELING OF GRAPHS

- The concept of labeling with magic property was first introduced by Kotzig and Rosa [1].
- The notion of Antimagic labeling was given by Hartsfield and Ringel in 1990 [2].
- Antimagic labeling of different graph products have been studied extensively in [3–11].
- Antimagic labeling have been studied widely and finds applications in cryptography and communication networks [12–16].

2.2 DISTANCE MAGIC LABELING OF GRAPH

- It is interesting to note that Sedláček [17] introduced a new kind of magic labeling referred to as magic labeling. The study of magic squares in number theory served as the inspiration for this labeling. Unlike today, when only integers are typically used, Sedláček's formulation permitted the use of any real number.
- A novel magic evaluation called distance magic labeling based on neighbourhood of vertices which is both magic and distance based was studied under different names in [18–20].

- Distance magic labeling of different products of graphs such as cartesian product, lexicographic product and direct product have been explored in [21–24].

- Magic square construction has served as a motivation for the idea of distance magic labeling of a graph. Finding equalised incomplete tournament $EIT(n, r)$, is identical to finding an r-regular distance magic labeling where the total strength of each team's opponents is k, and each team competes against exactly r other teams in an equalised incomplete tournament $EIT(n, r)$ of n teams with r rounds. This idea was initiated by Froncek in [25] and further developed in [26, 27].

2.3 DISTANCE ANTIMAGIC AND INCLUSIVE DISTANCE ANTIMAGIC LABELING OF GRAPH

- Distance antimagic labeling is a variant of distance magic labeling that was put forth by Kamatchi and Arumugam [28]. In this labeling, each vertex weight is a unique integer.

- Further, the idea of distance antimagic labeling was extended to inclusive distance antimagic labeling by [29] in which the vertex weight is defined as the sum of label of the vertex along with labels of all adjacent vertex labels.

- The distance antimagic labeling of different classes of graphs and some types of graph products has been examined in [30–37].

- Subsequently, the investigation of the antimagic features of graph products was constrained. Furthermore, there have been no additional investigations on inclusive distance antimagic labeling.

CHAPTER 3

DISTANCE ANTIMAGIC LABELING OF GRAPHS AND SOME PRODUCT GRAPHS

Antimagic labeling is used by the Advanced Encryption Standard (AES), a block cipher cryptographic technology, to encrypt data in blocks. Labeling a graph with predetermined arc labels is analogous to X-ray crystallography. The labeling method proposed in this study, distance antimagic labeling of graphs, is easily applicable to engineering, networking, or industrial tasks that need to establish connections analogous to the graphs investigated.

Algorithms were utilised in the initial section of the chapter to identify distance antimagic labeling for certain graphs, which would have been difficult to achieve manually. Existence of distance antimagic labeling is determined for Kneser graphs, crown graphs and several cycle related graphs which are crucial for different applications in engineering fields. Also, the non-existence of distance antimagic labeling of some graphs are proved.

In the next part of the chapter, results on distance antimagic labeling of various products of graphs such as cartesian product, lexicographic product, strong product and tensor product are discussed. Moreover, the distinctness of vertex weights are verified using computer programming.

The chapter contains numerous results in the form of theorems and illustrations. Important theorems proved in the chapter are listed below.

Theorem 3.0.1. *The Kneser Graph $K(n,2)$ is not (a,d)-distance antimagic for any n, $n > 4$.*

Theorem 3.0.2. *Assume that graph G has n vertices and is r-regular.. Then $G\square K_3$ is distance antimagic if G is monotonic decreasing and $r > \sqrt{2n-1}$, $r > \frac{1+\sqrt{1+8n}}{2}$ or $r > n + \sqrt{n^2-1}$.*

CHAPTER 4

INCLUSIVE DISTANCE ANTIMAGIC LABELING OF GRAPHS AND SOME PRODUCT GRAPHS

This chapter discusses inclusive distance antimagic labeling of various graphs, including closed helm graphs, helm graphs, and other families of disconnected graphs, and uses computer-aided procedures to assess the distinctness of vertex weights.
Graph products are important in the study of graph theory because they enable the investigation of complicated networks and systems. Furthermore, research on graph products advances a variety of theoretical and applied domains by deepening our understanding of the combinatorial and algebraic elements of graph theory. In this chapter, we also present results on inclusive distance antimagic labeling of certain graph products such as corona, join, cartesian, and rooted products.
Some of the results listed in this chapter are mentioned below.

Theorem 4.0.1. *Consider a graph G with n vertices and maximum degree Δ. $G + K_1$ is inclusive distance antimagic if G is inclusive distance antimagic.*

Theorem 4.0.2. *Let G be a graph on n vertices that is t-regular except complete graph, then $\frac{(t+1)(t+2)}{2} \leq \omega(a) \leq n(t+1) - \frac{t(t+1)}{2}$, for any vertex a in $V(G)$.*

CHAPTER 5

DISTANCE ANTIMAGIC LABELING OF SPECIAL GRAPHS

The class of special graphs, such as Mycielski graphs, splitting graphs, and shadow graphs, is an important area in both theoretical graph theory and applications. Special graph transformations and constructions allow deeper insight into graph properties, extensions of classical results, and practical applications in various fields.

These graphs are useful for checking conjectures, investigating invariants such as the chromatic number and the independence number, and to understand what changes in properties graph transformations produce. They generalize or extend previous results on graphs in order to establish new relations between graph invariants.

In this chapter, we examine distance antimagic and inclusive distance antimagic labeling of Mycielski graphs, splitting graphs and shadow graphs. Some results included in this chapter are listed below.

Theorem 5.0.1. *Splitting graph of the path P_n is inclusive distance antimagic.*

Theorem 5.0.2. *Mycielskian graph of the cycle C_n is distance antimagic when n is odd.*

Theorem 5.0.3. *Splitting graph of the star graph $K_{1,n}$ is inclusive distance antimagic.*

CHAPTER 6

APPLICATIONS OF DISTANCE ANTIMAGIC GRAPHS

A significant concern with the growing usage of the internet and other technologies is data security during data transport. Algorithms in cryptography are based on mathematical ideas to improve data transfer security. In the field of cryptography, the use of labeled graphs is becoming a valuable source for creating improved encryption techniques for safer data transfer between two parties because it is difficult or impossible to detect or know the type of graph used, i.e., the structure of the graph and the kind of graph labeling scheme used. Due to the capability to create unique and distinct values on graph structures, distance antimagic labeling can be used to powerfully design cryptographic systems. The graph-theoretic basis of distance antimagic labeling enables cryptography, which offers safe communication protocols, dynamic and unique key creation, and hash functions that improve security through mathematical rigour and structural complexity.

In this chapter, concept of distance antimagic and inclusive distance antimagic labeling are used to device algorithms for encryption of data with the assistance of XOR gate,

modulo operation and matrix methods.

CHAPTER 7

SUMMARY AND CONCLUSIONS

The thesis explores distance antimagic labeling of graphs and their products, emphasising both theoretical developments and practical applications. In graph theory, the field of distance antimagic labeling focusses on giving labels to vertices of graph that satisfy certain mathematical conditions, making the sums of the distances associated with these labels unique. This fascinating field tackles issues that are frequently too complicated to handle manually by combining computer techniques and combinatorial mathematics. First, the problem of calculating distance antimagic labeling for particular graph classes is addressed in the thesis. The challenges associated with manual computations, particularly for big or complex graphs overcame using computer-assisted programming. In order to generate answers and validate results that would otherwise be unavailable, this computational method proves to be crucial. In addition, the paper investigates distance antimagic labeling for Cartesian, tensor, and strong products of graphs. In doing so, patterns and conclusions regarding the behaviour of such a labeling under graph operations is established. With a focus on graph products, the study offers a comprehensive grasp of how to apply and expand such a labeling framework across various graph frameworks.

Another section of the thesis discusses results on inclusive distance antimagic labeling.The next logical step after studying distance antimagic graphs is to examine inclusive distance antimagic graphs in order to expand and enhance our knowledge of graph labeling in more intricate and inclusive contexts.

This work significantly advances the study of inclusive distance antimagic labeling and

distance antimagic labeling for particular graph classes such as splitting graphs, shadow graphs, and Mycielski graphs. To further strengthen the field's theoretical foundation, rigorous proofs for the graph families stated above are provided. The flexibility and generalisability of the distance antimagic framework are demonstrated by these results, which showcases broader perspective of the labeling.

The final part of the thesis discusses the practical application of distance antimagic labeling in cryptography. Algorithms are designed to encrypt data from plaintext to ciphertext due to immense potential of graph labeling in secure communication. These algorithms use the unique properties of distance antimagic labeling to enhance data security, thus showing the relevance of this mathematical framework beyond pure theory.

Establishing the framework for the following chapters, the literature review offers a thorough analysis of distance antimagic and inclusive distance antimagic labeling in addition to various graph products. A concise outline of definitions and goals helps the reader navigate the subsequent sections.

The following chapters carefully address the research objectives, including the development and analysis of distance antimagic labeling, computer-assisted labeling computation, practical applications in cryptography, and extensions and analysis of distance antimagic labeling. The findings are provided in the form of definitions, theorems, and demonstrations, providing a foundation basis for additional study.

Overall, this thesis represents a significant contribution to the study of distance antimagic labeling and its applications. It extends the mathematical knowledge of graph labeling and the theoretical possibilities in applications like encryption by combining computation, theoretical research, and real-world application. In both theoretical graph theory and applied mathematics, rigorous analysis and algorithmic design bring forth new research avenues.

CHAPTER 8

FUTURE WORK

- Extend the study of distance antimagic labeling to broader classes of graphs such as Harary graph, Generalised Peterson graph or dynamically evolving Random graph.
- To further extend the study of distance antimagic labeling to other types of labeling.
- To verify and validate theoretical results using real-world problems such as social network, communication network or biological systems.
- Develop stronger encryption algorithms based on distance antimagic labeling with an emphasis on efficiency and attack resistance.
- To forecast labeling patterns and validate findings, making use of contemporary computational tools like machine learning or parallel computing.

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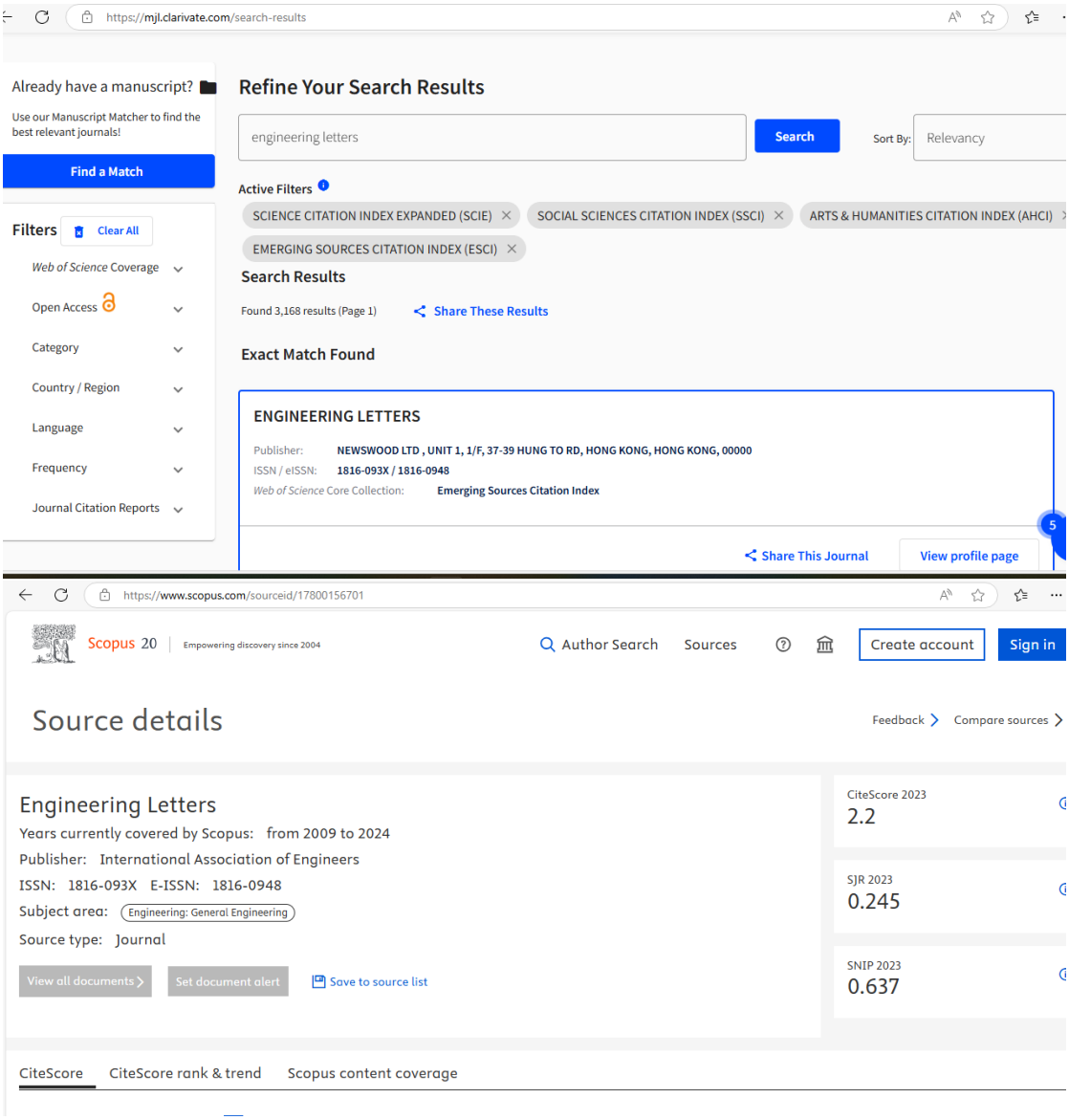

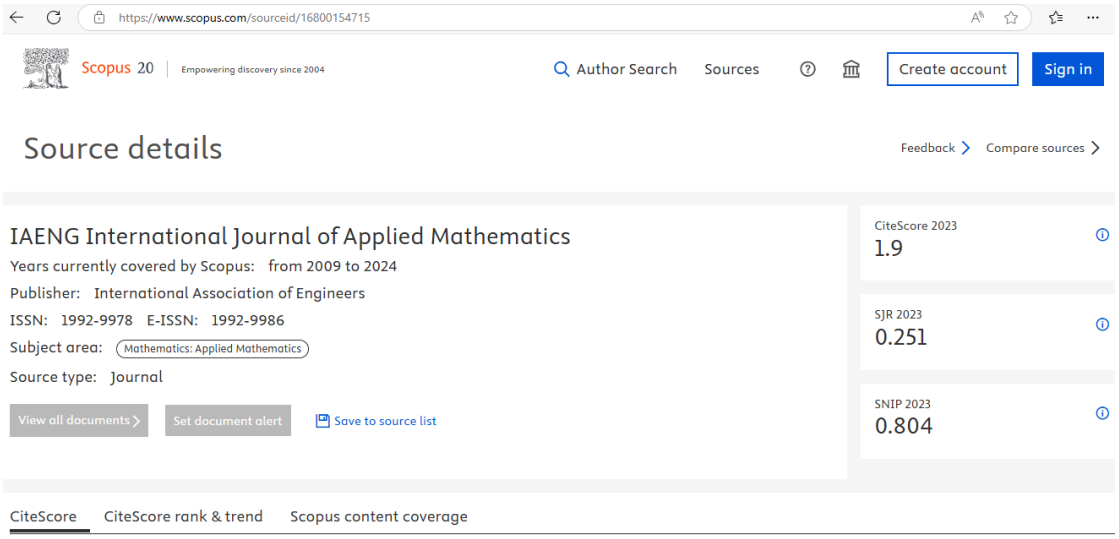
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